

Glossary

Aberration- Discontinuity or distortion in an image produced by a lens. In astronomy, the apparent change in direction of a source of light caused by an observer's motion.

Absorption Spectra- The spectra of electromagnetic radiation transmitted through a substance, with dark lines indicating the absorption of specific wavelengths. The dark lines indicate the absorption of photons at frequencies specific to that particular element or molecule.

Acceleration- The rate of change of velocity per unit of time. Acceleration implies that either an object's speed (rate of change of position) or direction of motion is changing.

Accelerating Universe- A cosmological term referring to the discovery that Hubble Expansion is speeding up over time, rather than slowing under the influence of gravity

Angular Size- A measure of size based on the angle that the object subtends, or covers. For example, the moon subtends an angle of $1/2$ of a degree. If the distance to an object is known, the angular size (the angle of $1/2$ a degree) can be used to determine its diameter.

Anisotropy- Physical property values that vary when measured from different directions. In cosmology, anisotropies refer to the difference in temperature of the CMB with direction.

Annihilated/Annihilation- A process in which a particle meets its corresponding antiparticle and both disappear. This apparent loss in energy appears in some other form, perhaps as a different particle and its antiparticle (and their energy), perhaps as many mesons, perhaps as a single neutral boson. The produced particles may be any combination allowed by conservation of energy and momentum and of all the charge types.

Anomaly- A deviation from the ordinary. Something peculiar or unusual.

Antiparticle- A particle type that has exactly the same mass but the opposite value of all other charges from its corresponding particle. For example, the antiparticle of an electron is a particle of positive electric charge called the positron.

Antimatter- Matter made up of elementary particles whose masses are identical to their normal-matter counterparts but whose other properties, such as electric charge, are reversed. The positron is the antimatter counterpart of an electron, with a positive charge instead of a negative charge. When an antimatter particle collides with its normal-matter counterpart, both particles are annihilated and energy is released.

Apparent Brightness- The brightness of an object as it appears without taking into account the distance from the observer to the object. For example, the sun appears to be the brightest object in the sky but is really dimmer (has less intrinsic luminosity) than many other stars.

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Atoms- The smallest unit of matter that possesses chemical properties. All atoms have the same basic structure: a nucleus containing positively charged protons with an equal number of negatively charged electrons orbiting around it. In addition to protons, most nuclei contain neutral neutrons whose mass is similar to that of protons. Each atom corresponds to a unique chemical element determined by the number of protons in its nucleus.

Background Radiation- Radiation filling all space. For example, the Cosmic Microwave Background Radiation from the early, hot universe is visible through out the universe today.

Baryon- Subatomic particles comprised of three quarks having a mass equal to, or greater than, a proton. Protons (comprised of two up quarks and one down quark) and neutrons (made up of two down quarks and one up quark) are examples of baryons.

Baryonic Matter- Matter comprised of protons and neutrons.

Big Bang- The violent cosmic explosion of an incredibly small amount of matter at high temperature and density approximately 20 billion years ago.

Black Body Spectrum- A plot of intensity of radiation versus wavelength for an object that absorbs all electromagnetic radiation.

c (speed of light)- The speed that light travels in a vacuum. It is about 3×10^8 m/s (186,000 miles/s). This is the maximum speed that any particle (including light) or information can travel.

Closed Universe- A model of the universe in which there is sufficient gravitational force to stop the expansion initiated by the Big Bang and the geometry of space closes upon itself like the surface of a sphere. For a universe containing only ordinary matter this means that it must have more than the critical density, $\Omega > 1$.

Cluster- A group of galaxies held together by the force of gravity.

Constant of Proportionality- A number that relates the units of two quantities in a mathematical relationship. For example, if you knew that force multiplied by distance was proportional to work, but you wanted a concrete equation, you could say force x distance=(constant) x work. The (constant) is the constant of proportionality. You could find it by plugging observed data into the equation and solving for it.

Cosmic- Of or relating to the universe as a whole.

Cosmic Microwave Background (CMB)- Ancient radiation leftover from a time roughly 380,000 years after the Big Bang when the hot, dense plasma that permeated the Universe cooled with the expansion of space. At a nearly uniform temperature of 2.7 Kelvin, the CMB fills the entire universe.

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Cosmological Constant (Λ),- The energy density of the smooth vacuum. Einstein initially introduced the term into equations as a way to counteract the attraction caused by gravity at large scales, while preserving the hypothesis of the static universe. He would later regret this move calling it his "greatest blunder."

Cosmological Principle- The principle that the Universe is homogeneous and isotropic. That is, when viewed on sufficiently large distance scales, there are no preferred directions or preferred places in the universe: it looks the same in all directions for an observer anywhere.

Cosmology- The scientific study of the origin, evolution, and fate of the universe.

Coupled to Radiation- Matter that is strongly influenced by the presence of radiation.

Critical Density- The calculated mass density of the universe that stops the expansion of space. Critical density is the dividing line between models of the universe that expand forever ("open models", and those that recollapse ("closed models").

Curvature of Space-time- The distortion of space and time by the presence of matter as dictated by Einstein's General Theory of Relativity.

Dark Energy- The force or energy postulated by cosmologists to explain the acceleration of the expansion of the universe. Presently, Dark Energy is detectable only through its gravitational effects.

Dark Matter- Matter that emits no observable radiation but is detectable through its gravitational effects.

Deceleration- Decreasing velocity.

Density Fluctuations in Matter- Regions of greater and lesser mass density, which can form into large-scale cosmological structures such as galaxies, clusters, etc.

Deuterium- A special form of hydrogen (an isotope called "heavy hydrogen") that has a neutron as well as a proton in its nucleus.

Doppler Effect- The apparent change in frequency of a wave due to the relative motion of the source and observer. For example, when the source and observe move apart, the wavelength is stretched, lowering its frequency.

Dynamics- The branch of mechanics in physics concerned with the effect of forces on the motion of bodies during a particular length of time.

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Electromagnetic Force- The fundamental force that binds electrons to atoms and governs the physics of light. Any charge feels an electric force from another charge, while a moving charge feels a magnetic force from another other moving charge.

Electromagnetic Radiation- A kind of radiation including radio waves, microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays. Electromagnetic radiation is created when electric fields and magnetic fields vary simultaneously.

Electron- A negatively charged elementary particle that typically resides outside the nucleus of an atom, but is bound to it by electromagnetic force.

Elementary Particle Physics- The study of the properties, relationships, and interactions of fundamental, subatomic particles (such as quarks and leptons).

Energy Density- The amount of energy per unit volume. The energy density affects, and is affected by, the expansion or contraction of the universe.

Equilibrium- To be in a state of perfect balance. As long as the system (what ever is in balance) is untouched by external forces, it remains in balance. All systems naturally fall toward a state of equilibrium. For example, a spinning top is in a kind of equilibrium until it falls, where it enters a different state of equilibrium.

Era- A time period in the evolution of the universe dominated by a particular physical process.

Evolution- The gradual development of something over a period of time.

Extrapolate- To extend an estimate or conclusion to an unknown situation by assuming existing trends will continue.

Finite- Having limits or bounds, a set amount.

Fission- The process by which a heavy nucleus breaks apart into two, more stable nuclei, resulting in a release of energy.

Flat Universe- A model of the universe where space is not curved, but is instead, geometrically flat. In a flat universe, the total energy density equals the critical density. That is, $\Omega=1$.

Flatness Problem- A question in cosmological physics that asks what has caused the universe to be so flat given that under the influence of gravity, any non-flat area should quickly get larger. For example, a closed universe should recollapse, while an open universe should expand so that no two objects are near one another. The Flatness Problem essentially asks why the universe is balanced between these two extremes.

Fluctuation- A variation in quantity from the average.

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Flux- In astronomy, the rate of flow of radiant energy across a given area.

Frame of Reference- The perspective from which an event is viewed.

For example, a man is standing on the side of the road, and he sees a woman drive past him in a car. From the man's frame of reference, he is stationary and the woman is speeding past him at 40 miles per hour. However, from the woman's frame of reference, the man appears to be speeding past her in the opposite direction but at the same speed. Measurements of an event (like speed or direction) are taken from an "Inertial Frame of Reference, which is an imaginary static point where events are viewed. If the speed of a spaceship is to be measured from earth, then the earth is the inertial frame. While the Earth is not actually stationary (it turns on its axis and revolves around the sun), for the purposes of measuring, it is said to be.

Fundamental Interactions- In physics, the strong, electromagnetic, weak, and gravitational interactions, or forces. These forces are the mechanisms that govern every observed physical phenomenon, and cannot be explained in terms of other interactions.

Fundamental Particles- The smallest and most basic constituents of matter that transmit the fundamental interactions. In the Standard Model, quarks, leptons, photons, gluons, W^+ and W^- bosons, and the Z bosons are fundamental. All other known particles are comprised of these fundamental particles.

Fusion- The process by which two or more nuclei of low atomic number or baryons fuse to form a heavier nucleus with a release of energy.

Galaxy- A cluster of billions of stars, gas, and dust held together by gravity. Galaxies come in a variety of shapes (elliptical, spiral, etc.) and sizes. While galaxies are incredibly luminous, physicists speculate that most galactic mass comes from Dark Matter.

General Relativity- A theory that describes gravity as the curvature of space and time due to the presence of mass (rather than a force, as it is treated in classical, Newtonian mechanics) first published by Albert Einstein in 1915.

Geocentric- A model of the universe, developed by the Greek astronomer Ptolemy, that places the earth at the center of the universe with the sun and planets located in rotating, concentric, crystalline spheres surrounding Earth.

Geometries- Models of curvature in which the laws of geometry differ depending on the whether the universe is flat, spherical, or saddle-shaped.

Globular Clusters- A ball-like structure of a few hundred thousand old stars that resides in the halo of a galaxy.

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Gluon- An elementary particle that allows for the interaction of quarks, as well the binding of protons and neutrons together in atomic nuclei via the Strong Force.

Gravitational Attraction- The force of attraction between all bodies with mass.

Hadron- A subatomic particle made up of quarks such as protons and neutrons. All hadrons interact via the Strong Force and are subject to gravity, while charged hadrons are influenced by Electromagnetic Forces.

H₀, Hubble Constant- A measure of the present expansion rate of the universe, named after Edwin Hubble who discovered that the redshifts of galaxies are directly proportional to their distance from the Milky Way. Current techniques measure the Hubble Constant to be approximately between 70 and 80 meters per second per mega parsec (A mega parsec is equal to 3.26×10^6 light-years).

Heliocentric- A model first proposed by Nicolaus Copernicus that places the sun, fixed near the center of the universe, with the Earth and other planets making revolutions once a year.

Homogeneous- The same at every location.

Hubble's Law- The law, formulated by Astronomer Edwin Hubble in 1929, that states the redshift in light coming from distant galaxies is proportional to their distance from the Earth. Hubble's Law is considered to be one of the first pieces of observational evidence for the Big Bang.

Hypothesis- A proposed explanation made on the basis of limited evidence, used as the starting point for further investigation as described by the Scientific Method.

Inflation- A phase of the early universe marked by rapid, accelerating expansion. Inflation helps explain why the universe appears flat, homogeneous, and isotropic.

Inhomogeneity- Something not evenly distributed in space; a clump or cluster.

Initial Conditions- The nature of a system's state when time equals zero.

Intensity- The energy moving through a region of area per unit of time. Intensity is proportional to the light's photon density (the number of photons contained in a square meter).

Intrinsic Luminosity- The amount of energy actually emitted into space by an object, as opposed to how bright the object appears from Earth.

< Inverse Square- 1 divided by a quantity squared: $1/(r^2)$.

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Ion- An atom or molecule with a net electric charge (either positive or negative) resulting from a loss or gain in number of electrons.

Isotopes- Atoms that have the same number of protons, but a different number of neutrons.

Isotropic- Having the same value regardless of direction measured.

Kelvin- The SI base unit of temperature. The coldest possible temperature of anything is 0 Kelvin which corresponds to -273 degrees on the Celsius scale.

Lambda: The Cosmological Constant, Λ - A constant representing the energy density of the smooth vacuum. It was first postulated by Albert Einstein to counteract the attraction of gravity at large distance scales to preserve the hypothesis of a static universe.

Large Scale Structure- Galaxies, galaxy clusters, and galaxy superclusters.

Last Scattering Surface- The farthest back in the history of the universe that photons could travel freely. In the early universe, all matter was ionized and interacted with photons, preventing us from seeing light from longer ago. The last scattering surface is where today's CMB photons last scattered off this ionized matter.

Lepton- Elementary subatomic particles, such as the electron, that do not experience the Strong Force. Leptons can have either a positive or a negative electric charge, depending on whether they are particles or antiparticles.

Light- A general term for electromagnetic radiation, usually referring wavelengths within the visible part of the electromagnetic spectrum.

Light Cone- A region of space-time (shaped like two cones placed peak to peak) that can be used to describe the history of an event. For example, if a pulse of light is emitted from a flashlight, the top, or future cone, represents the future history of the pulse of light while the bottom (or past cone) represents the directions light could have been received at an event in the past.

Light-year- The distance light travels in a year: approximately 9.5 trillion kilometers (5,880,000,000,000). A light-year is approximately 63,000 times as long as the distance from the Earth to the Sun.

Local Group- A small cluster of more than 30 galaxies in the neighborhood of our galaxy (the Milky Way), including the Andromeda galaxy and the Magellanic Clouds. The Local Group appears to be part of a larger supercluster of galaxies that lies around 60 million light-years away in the direction of the constellation Virgo.

Luminosity- The total energy released by an object that emits light (for example, a star), per unit of time. Luminosity may also refer to the power (energy per time) of a star.

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Luminosity is an intrinsic quality of a star: it does not matter where you are (neglecting relativistic effects), a star will always have the same luminosity. For most stars, their luminosity is dependent on their mass.

Luminous Matter- Ordinary, visible matter. It is composed of baryons, as opposed to dark matter.

Main Sequence Star- The average star in the universe. These stars tend to be somewhat small and are powered by hydrogen fusion. They are so named because they lie along a continuous band, the "main sequence", on the Hertzsprung-Russell diagram.

Mass Defect- The mass that is converted to energy during a nuclear reaction. When two subatomic particles are bound together, their combined mass is slightly more or less than their masses would be if each particle were measured separately. During fusion or fission, the difference in mass is turned into energy, as per Einstein's famous $E = mc^2$

Milky Way- The galaxy we live in. When viewed from the Earth, it looks like a hazy band of white light (hence "milky") consisting of distant stars. The Milky Way is a large spiral galaxy, about 100,000 light years across, with a total mass of about 10^{12} solar masses, comprising 200-400 billion stars.

Model A cosmological model is a theory which describes the evolution and structure of the universe. There are three primary models of the universe: one that expands forever, one that eventually collapses, and one that stays the same size.

Muon- A large fundamental particle. Designated μ^- (mu), it is the second heaviest lepton (behind the Tau), and it has the same negative electric charge as an electron.

Neutrino- A tiny elementary particle with no electric charge. Denoted by ν (nu), neutrinos travel close to the speed of light and have almost no mass, making them very difficult to detect. They are leptons, and are three known varieties.

Neutron- A subatomic particle found in the nucleus with zero electric charge. Different isotopes are distinguished by the number of neutrons in their nuclei. It is a baryon that consists of two down quarks and one up quark (held together by gluons).

Naught- The initial value. Denoted by a subscript, "0", it refers to the first among a range of values. For example, if an object started off traveling 30 meters/second, then v_0 , or 'velocity naught', = 30.

Nucleon- A proton or neutron. It refers to either baryon that makes up an atomic nucleus.

Nucleosynthesis- The process that bigger atoms out of subatomic particles and smaller atoms. Also called fusion, it occurs in the intense heat of stars or thermonuclear explosions.

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Nucleus- The small, positively charged center of an atom. Although the nucleus is 100,000 times smaller than the atom, nearly 100% percent of the atom's mass is in the nucleus. The nucleus is composed of protons and neutrons.

Observed Brightness- How bright an object looks from earth. Defined as the flux of light emitted by the object as measured on earth, it is inversely proportional the distance to the object squared, as opposed to the how bright the object is up close. For example, the full moon has a greater observed brightness than the star Vega, even though Vega has a greater luminosity.

Omega; Density Parameter, Ω - The ratio of the total density of matter to the critical density required to make the universe flat. For example, if $\Omega = 1$, the total density is the same as the critical density.

Opaque- Not able to be seen through. When radiation (like light) is absorbed or scattered many times, whether by plasma at the beginning of the universe or by the top of your desk, we can only see the object and nothing behind it.

Open Universe- A universe where space is curved like a saddle. An open universe has less mass than the critical density ($\Omega < 1$), and it expands forever.

Parallax- A method of finding astronomical distances. Using a distant background of stars as a reference plane, one observes an object moving across the sky as the earth moves around the sun. The closer the object, the bigger its parallax motion.

Parsec- A unit of length used in astronomy. Equal to 3.1×10^{13} km or 3.26 light years, its name means it is the distance to a star with a Parallax of one Second.

Particle Accelerators- Machines used to propel particles to high speeds. They use electric fields to contain and accelerate charged particles.

Particle Physics- The study of fundamental particles (such as quarks and leptons) and their fundamental interactions (four forces).

Period- The time between two peaks of a wave. Usually designated by T, this is the time it takes a wave to make one complete oscillation.

Phase Transition- Change from one state of energy to another.

Photon- An elementary particle that makes up electromagnetic radiation (including light). Even though a photon is a particle, it is still a wave and has a wavelength, frequency, and so on like any other wave. Unlike many other particles, a photon has no mass.

Planck Time / Length- The shortest possible units of time and length. A Planck time is about 5.4×10^{-44} seconds, and a Planck length is about 1.6×10^{-35} meters. At any smaller time or length, our current understanding of physics would break down.

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Plasma- A state of matter composed of free charged particles. Plasma, such as fire, stars, or lightning, consists of high energy ions and electrons. A gas becomes a plasma, or ionized gas, when electrons have enough energy to escape from their atoms.

Positron- The antiparticle of the electron. It carries a charge exactly opposite that of an electron.

Primordial- Earliest, original, or initial. **Primordial Nucleosynthesis-** Building of atomic elements in the early universe, when temperatures were high enough to fuse nuclei together. Most of the helium in the universe was created by this process.

Probability Density- The likelihood of an object being found in a particular location. In quantum mechanics, it is impossible to know an object's exact location; a high probability density tells us where the particle is most likely to be found.

Proton- A subatomic particle found in the nucleus with positive electric charge. The number of protons in an atom determines its element. It is a baryon that consists of two up quarks and one down quark (held together by gluons).

Quantum Fluctuations- Tiny, temporary changes in the energy of a vacuum. Because of inherent uncertainties at subatomic scales, energy is not guaranteed to be conserved.

Quantum Mechanics- A theory of physics that applies to systems on extremely small scales (ie, the size of an atom). Quantum mechanics describes the "fuzziness" of the universe. It can only predict the probability that an event will happen.

Quark- A fundamental particle that interacts through the strong force. Quarks have an electric charge of either $+2/3$ (up, charm, top) or $-1/3$ (down, strange, bottom) the charge of a proton. They are the basic building blocks of hadrons (protons, neutrons, and mesons).

Quasar- Short for QUASI-stellar radio source. A quasar is the nucleus of a young galaxy powered by a super massive black hole. Every so often the black hole devours some form of mass and becomes extremely bright. The brightest known quasar is more than one hundred times as bright as our entire galaxy, even though it is only several light weeks across (as opposed to the Milky Way - 100,000 light-years across).

Radiation- Energy that is carried in waves. It includes electromagnetic energy and subatomic particles moving close to the speed of light.

Radiation Pressure- The pressure caused by light or other radiation. When any kind of electromagnetic radiation hits a surface, it transfers momentum to the object, potentially propelling it forward.

Recede- To move away from the observer (us, in most cases).

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Redshift- An increase in the wavelength of light. This can arise from motion of the source or receiver (Doppler shift), expansion of space, or strong gravitational fields.

Relative Brightness- How bright one object is compared to another. Even if two objects have the same intrinsic brightness, their relative brightness tells us which is closer and by how much.

Relic- Anything left over from a previous time period. In cosmology, they include evidence of early physical eras.

Scatter- When an object absorbs light from one direction and then emits light in all directions. For example, when light from our sun comes into contact with the clouds in our atmosphere, it is absorbed by the clouds and the re-emitted in all directions. On a clear day, sunlight comes from a small point (the sun), but on cloudy days it seems to come from all directions.

Scalar- A constant number. 1, -16, .3534, 7346 are all scalars.

Simultaneous- Occurring at the same time

Spacetime- The combination of space and time into a four dimensional universe. The first three are spatial: up/down, north/south, east/west; the fourth is temporal: past/future.

Spectrum- A range of possible measurements. In physics, a spectrum usually refers to all the different wavelengths or colors (if in the visible range) of light.

Spectral Line- A line that appears in an otherwise uniform spectrum at a specific frequency or wavelength. They are due either to emission of light, which makes a bright line, or absorption of light, making a dark line.

Standard Candle- A celestial object whose intrinsic brightness is known or can be well estimated by some physical principle. Because we can see its observed brightness as well, we can determine its distance.

Static- Unchanging over a length of time

Steady State Theory- An cosmological model that says the universe has always been and will always be the same as it is now. It claims that the universe is homogenous and isotropic not just in space, but throughout time. The discovery and analysis of the Cosmic Microwave Background Radiation, however, has provided conclusive evidence against the Steady State Theory.

Stochastic- Random

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Strong Force- The extremely strong but extremely short-range attractive force. It is the interaction responsible for binding quarks and antiquarks together to make hadrons, such as protons and neutrons. The leftover strong interactions make up forces that keep the nucleus together.

Supercluster- A group of galaxy clusters. A supercluster may contain tens of thousands of galaxies spanning over a hundred million light-years of space. Galaxy superclusters are the largest confirmed structures in the universe.

Supernova- An enormous and extremely bright explosion of a star at the end of its lifetime. Dying stars that grow too large may collapse in on themselves, or white dwarfs that get too heavy may trigger a thermonuclear explosion. The shock waves and expelled matter from supernovae are responsible for the birth of new stars.

Type Ia Supernova- A supernova formed from the explosion of an old, compact star (white dwarf). Because of their uniform brightness, they make good standard candles.

Universe- All of space and time, along with all the matter and energy in it.

Vacuum Energy- Energy that has been theorized to exist everywhere in space, which arises from quantum mechanics.

Variable Stars- Stars which brighten and dim, some with precise timing. For Cepheid variables (one type of variable star), their period allows us to find their brightness, and from that we can determine their distance.

Velocity- The speed of an object and the direction in which it is moving. It tells how fast and in what direction an object's position changes.

Visible Mass- Mass that can be detected, or seen. We see it by detecting the electromagnetic radiation that it gives off. It is also referred to as ordinary (baryonic) matter.

Visible Universe- The part of the entire universe close enough for light to have had enough time to reach us in the age of the universe. Currently, it includes everything less than 13.7 billion light years away.

Wavelength- The distance between two peaks of a wave. Usually designated by λ (lambda), it is the distance it takes a wave to make a complete oscillation. For visible light, this is on the order of 500 nanometers.